TOWARDS A GENERAL EQUATION FOR THE SURVIVAL OF MICROBES TRANSFERRED BETWEEN SOLAR SYSTEM BODIES.

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Introduction: It should be possible to construct a general equation describing the survival of microbes transferred between Solar System bodies. Such an equation will be useful for constraining the likelihood of transfer of viable organisms between bodies throughout the lifetime of the Solar System, and for refining Planetary Protection constraints placed on future missions. We will discuss the construction of such an equation, present a plan for definition of pertinent factors, and will describe what research will be necessary to quantify those factors.

Description: We will examine the case of microbes transferred between Solar System bodies as residents in meteorite material ejected from one body (the "intial body") and deposited on another (the "target body"). Any microbes transferred in this fashion will experience *four distinct phases* between their initial state on the initial body, up to the point where they colonize the target body. Each of these phases features phenomena capable of reducing or exterminating the initial microbial population. They are:

1) Ejection: Material is ejected from the initial body, imparting shock followed by rapid desiccation and cooling.

2) Transport: Material travels through interplanetary space to the target body, exposing a hypothetical microbial population to extended desiccation, irradiation, and temperature extremes.

3) Infall: Material is deposited on the target body, diminishing the microbial population through shock, mass loss, and heating.

4) Adaptation: Any microbes which survive the previous three phases must then adapt to new chemophysical conditions of the target body. Differences in habitability between the initial and target bodies dominate this phase.

A suitable general-form equation can be assembled from the above factors by defining the initial number of microbes in an ejected mass and applying multiplicitive factors based on the physical phenomena inherent to each phase. It should be possible to present the resulting equation in terms of initial ejection mass, ejection shock magnitude, transfer time, initial microbial load and/or other terms and generate graphs defining the number of surviving microbes. The general form of the equation is:

$$x_f = x_i f_1 f_2 f_3 f_4$$

Where x_f is the final number of microbes to survive transfer, x_i is the initial population prior to ejection, and $f_{1\text{-}4}$ are mortality factors for the four phases described above. Among other considerations, f_1 will vary with respect to impact shock magnitude and f_2 will be time-dependent.

Considerable research has been performed to date to quantify the survival rates of various microbes in response to portions of these four phases, both as vegetative cells and/or spores [e.g. 1-4]. Results indicate that many species tend to respond differently to the pertinent mortality factors, especially in the case of extremophiles. Therefore, a complete equation will include species-specific responses to the mortality factors.

References: [1] Hornek G. *Adv. Space Res.* (1981) 39-48. [2] Hornek G. *et al Astrobiology* **8** (2008) 17-44. [3] Koike J. *et al Adv. Space Res.* **12** (1992) 271-274. [4] Mastrapa R. EPSL **189** (2001) 1-8.